A MODULAR MEZZANINE CONNECTOR

Field of the Invention

This invention relates to a modular board to board mezzanine style connector.

Background of the Invention

Ball grid array (BGA) connectors are generally known in the art and a general discussion of such connectors can be found in United States Patent No. 5,730,606. In these types of connectors an integrated circuit is mounted to a plastic or ceramic substrate with a ball grid array, which generally includes spherical solder balls that are positioned on electrical contact pads of a circuit substrate. These types of connectors can be mounted to an integrated circuit without using external leads extending from the integrated circuit. Among the advantages of ball grid array connectors are smaller package sizes, good electrical performance and lower profiles.

In prior mezzanine style connectors unique components were required for each connector stack height and gender. This invention includes a modular mezzanine style board to board connector that can be made to a selected stack height by choosing from a variety of common components that can mixed or matched to provide a desired stack height. Regardless of the stack height, the plug and the receptacle can be made using at least some of the same components. If a larger stack height is needed, additional components can be added.

Summary of the Invention

This invention includes a modular mezzanine connector that has a plug assembly and a receptacle assembly each of which have a common base. The plug assembly and the receptacle assembly can mate with each other to form a modular connector for connecting a variety of electrical components including printed circuit boards. Because the plug and the receptacle assemblies each have a common base, only one base needs to be mass produced in order to make both assemblies. This is advantageous because it simplifies manufacturing and reduces manufacturing costs.

The common base of the plug and receptacle assemblies may have a plurality of recesses and a plurality of diamond pockets disposed in an interstitial configuration. Preferably, there is a pocket beneath each recess so that a contact can extend through one of the recesses and into one of the pockets. The plurality of recesses are preferably substantially rectangular in shape so that a contact extending through the recess and into the diamond pocket can receive a fusible element, such as solder, around a periphery of a portion of the contact extending into the pocket.

The plug assembly may also include a plug cover and a plurality of plug contact assemblies. The plug cover may be attached to the base by any suitable means including snaps. The plug contact assemblies may each have a plurality of ground and signal contacts which are molded to a plastic carrier. In order to hold the plug contact assemblies in the plug assembly, the plastic carrier is inserted into slots within the base.

The plug cover may have a plurality of slots through which one end of each of the plug contacts of the plug contact assemblies extend. The other end of the plug contacts extends through the recess in the base into a pocket, and a solder ball is formed around the end of the contact in the pocket.

The receptacle assembly may also have a receptacle cover and a plurality of receptacle contact assemblies. Attached to the base may be the receptacle cover. Similar to the plug contact assemblies, the receptacle contact assemblies are preferably soldered at one end within a base pocket. Also similar to the plug contact assemblies, the receptacle contact assemblies preferably include a plurality of contacts which are molded to a plastic carrier. The plastic carrier can be inserted into the slots of the base.

The receptacle cover preferably has a plurality of slots with a receptacle

contact disposed beneath each slot. The receptacle assembly and the plug assembly are coupled together by mating the receptacle cover and the plug cover. Preferably, they can be coupled with a sliding fit. When coupled together, a plug contact extends through each of the slots in the receptacle cover and mates with a corresponding receptacle contact.

Both the plug and the receptacle assemblies can employ a common spacer for greater stack heights. The spacer can be attached to the base of either assembly and the respective plug or receptacle cover can be attached to the spacer. Any suitable means can be used to attach the components including snaps.

Other features of the inventions are described below.

Brief Description of the Drawings

Figure 1 is a top isometric view of a plug assembly according to a preferred embodiment of this invention;

Figure 2 is a bottom isometric view of a plug assembly according to a preferred embodiment of this invention;

Figure 3 is an assembly drawing of the plug assembly of Figure 1 with the plug cover removed;

Figure 4 is a top perspective view of a preferred embodiment of a common base for the plug assembly of Figures 1 and 2 and the receptacle assembly of Figures 17 and 18;

Figure 5 is a bottom perspective view of a preferred embodiment of a common base for the plug assembly of Figures 1 and 2 and the receptacle assembly of Figure 17 and 18;

Figure 6 is a perspective view of a portion of the top of the common base of Figure 4;

Figure 7 is a perspective view of a portion of the bottom of the common base of Figure 5;

Figure 8 is a cross-section taken along line 8-8 of Figure 1;

Figure 9 is a cross-section taken along line 9-9 of Figure 1;

Figure 10 is a perspective top view of a plug cover of the plug assembly of Figure 1 according to the preferred embodiment of the invention;

Figure 11 is a perspective bottom view of a plug cover of the plug assembly of Figure 1 according to the preferred embodiment of the invention;

Figure 12 is a cross-section taken along line 12-12 of Figure 10;

Figure 13 is a cross-section taken along line 13-13 of Figure 10;

Figure 14 is a perspective top view of a spacer according to a preferred embodiment of this invention;

Figure 15 is a perspective bottom view of a spacer according to a preferred embodiment of this invention;

Figure 16 is a perspective view of a plug contact assembly before being singulated;

Figure 17 is a top perspective view of a receptacle assembly according to a preferred embodiment of this invention;

Figure 18 is a bottom perspective view of a receptacle assembly according to a preferred embodiment of this invention;

Figure 19 is an assembly drawing of the receptacle assembly of Figures 17 and 18 with the receptacle cover removed;

Figure 20 is a perspective top view of a receptacle cover of the receptacle assembly of Figures 17 and 18 according to a preferred embodiment of this invention;

Figure 21 is a perspective bottom view of a receptacle cover of the receptacle assembly of Figures 17 and 18 according to a preferred embodiment of this invention;

Figure 22 is a cross-section taken along line 22-22 of Figure 17;

Figure 23 is a cross-section taken along line 23-23 of Figure 17;

Figure 24 is a perspective view of a receptacle contact assembly before being singulated;

Figure 24A is a schematic diagram of a preferred ground and signal contact configuration;

Figure 24B is a schematic diagram of a second preferred signal and ground contact configuration;

Figure 25 is a perspective view of a portion of a second preferred embodiment of a plug assembly;

Figure 26 is a perspective view of a portion of a second preferred embodiment of a receptacle assembly;

Figure 27 is a perspective top view of a second preferred embodiment of a common base for the plug and receptacle assemblies of Figures 25 and 26;

Figure 28 is a perspective bottom view of a second preferred embodiment of a common base for the plug and receptacle assemblies of Figures 25 and 26;

Figure 29 is a perspective view of a second preferred embodiment of a receptacle contact assembly;

Figure 30 is a side view of a portion of the receptacle contact assembly of Figure 29;

Figure 31 is a perspective view of a preferred embodiment of an adapter; and

Figure 32 is a schematic diagram of a preferred ground plane and signal contact configuration for the second preferred embodiment.

Detailed Description of Preferred Embodiments

The electrical connector may be a board to board mezzanine ball grid array (BGA) connector which includes a mated assembly having a plug assembly 12, a preferred embodiment of which is shown in Figures 1 and 2, and a receptacle assembly 13, a preferred embodiment of which is shown in Figures 17 and 18. The plug assembly 12 mates with the receptacle assembly 13 to form a connector. As described in more detail below, the plug assembly 12 and the receptacle assembly 13 have a common base 14. Thus, the manufacturing of the plug assembly 12 and the receptacle assembly 13 is simplified because the plug assembly 12 and the receptacle assembly 13 can be made from a common base 14. This is also beneficial because it reduces manufacturing costs.

PLUG ASSEMBLY

Top and bottom perspective views of the plug assembly 12 according to a preferred embodiment of this invention are respectively shown in Figures 1 and 2. The plug assembly 12 preferably includes the common base 14, a plurality of contact assemblies 16 and a plug cover 18. The plug assembly 12 may depending upon the

contact height include a spacer 20, which is depicted in Figures 14 and 15. As shown in Figure 1, the plug cover 18 is preferably mechanically coupled to the spacer 20 by any suitable means, including but not limited to the use of mechanical connections and adhesives. The spacer 20 is mounted to the base 14. This construction is also understood with reference to Figure 3 which depicts a portion of the plug assembly 12 with the plug cover 18 detached from the spacer 20. (Figure 3 depicts only a portion of the plug contact assemblies 16 installed, but it will be appreciated that the plug assembly 12 is filled with a plurality of such plug contact assemblies). Alternatively, for a lower stack height, the plug cover 18 can be mounted directly to the base 14, and a spacer 20 need not be used. (Although the plug assembly 12 is depicted in Figure 1 and the receptacle assembly 13 is depicted in Figure 17 as each having a cap 12a and 13a, it will be appreciated that these caps 12a, 13a (which can be the same cap) are used for manufacturing purposes and do not form part of the connector described herein. These caps 12a, 13a are for lifting the assemblies during handling and manufacturing. For example, the assemblies 12, 13 can be vacuum lifted by applying a suction to the caps 12a, 13a).

A preferred embodiment of the common base 14 for the plug assembly 12 and the receptacle assembly 13 is depicted in Figures 4 and 5. This base 14 is a common component that can be used to form both the plug and the receptacle. Figure 4 is top perspective view of the top 14a of the base 14, and Figure 5 is a bottom perspective view of the bottom 14b of the base 14. The base 14 may be constructed from any suitable material and is preferably a polymeric material. Moreover, the base can be constructed in a single piece as shown in the preferred embodiment, which is a single piece of molded plastic, or any number of pieces.

As shown in Figure 4, the top 14a of the base 14 includes a plurality of recesses 22. A closer view of a preferred embodiment of the recesses 22 is shown in the perspective view of Figure 6. Each of the recesses 22 are preferably defined by two pairs of opposing angled walls 24, 26. The angled walls 24, 26 approach each other but do not touch so that they in part define a recess 22. As explained in more detail below and as shown in Figure 8, one end of a plug contact of a plug contact assembly 16 fits within each recess 22 if the base is to be used as part of a plug assembly. Alternatively, if the base 14 is to be used as a base of a receptacle assembly, a receptacle of a receptacle contact

assembly can be inserted into the recess 22. The construction of the contact plug assemblies 16 is further described below.

Figure 5 depicts the bottom view of the perspective view of the base 14, and Figure 7 depicts an enlarged view of a portion of the bottom 14b of the base 14. As shown best in Figure 7, the recesses 22 are defined so that they are preferably substantially rectangular shaped. The bottom 14b of the base 14 has a plurality of pockets 25 which are defined by walls 27. The walls 27 are preferably configured to define the pockets in a diamond shape, as shown in Figure 7.

Moreover, a ball grid array connector, which is preferably a fusible element and even more preferably solder, can be disposed within each pocket 25 so that each fusible element is in electrical contact with a contact that extends through the recess 22. This is best understood with reference to Figures 8 and 9 which are cross-sections through the plug assembly 12 of Figure 1. In the embodiment shown the fusible element is a solder ball. The term ball is not meant to be limiting as to a particular geometric configuration of the solder. As shown in Figures 8 and 9 the solder balls 29 are disposed in the pockets 25 and the plug contacts extend through the base recesses 22 into the pockets 25. Each plug is wetted to a solder ball 29 in the respective pocket 25. The base 14 can be mated to an electrical component in order to form an electrical connection between the solder balls 29 and a circuit. For example, the base 14 can be mated to a board having an integrated circuit to form electrical connections between the solder balls and the circuit.

As shown in Figures 5 and 7, the pockets 25 are generally disposed in a pattern of alternating rows such that the centerline of each pocket 25 is aligned with a centerline of another pocket 25 that is two rows away from that pocket 25. Alternatively stated the pockets 25 are preferably disposed in an interstitial diamond shaped pattern. This diamond shaped interstitial pattern permits the contacts to be more closely packed while maintaining standard commercial pocket dimensions and using standard BGA solder balls. This diamond orientation also provides for additional clearance for the contacts. In particular, with the diamond pocket 25 of Figure 7, there will always be clearance around the entire periphery of the end of the contact extending through the recess even if the contact is not centered within the recess 22. In contrast, in some prior designs the recess

22 and the pocket 25 were both rectangular shaped and the contact if not centered could push against the walls which define the recess or pocket. In such designs, the potential exists that the solder would not extend around the entire periphery of the contact end if the contact was not centered within the recess 22. If solder does not surround the entire periphery of the contact end, then the mechanical integrity of the connection between the solder, the contact and another electrical component can be degraded.

As will be generally understood, the plug and the receptacle assemblies 12, 13 will undergo power and thermal cycles, which induce thermal stresses upon the contact and the solder. Having solder around the entire perimeter of the end of the contact is beneficial because areas of a contact end which do not have solder wetting (solder attached to the contact) are more susceptible to these stresses. Therefore, having solder around the entire perimeter of the contact can enhance ball retention and T-cycle life.

As best shown in Figures 4 and 5, the base 14 may also have a plurality of tabs 28 extending from opposing sides. These tabs 28 as explained further below fit with channels 38 disposed within the plug cover 18 (shown in Figures 10, 11), channels 43 in the spacer 20 (shown in Figures 14 and 15) or channels 80 in the receptacle cover 70 (which is described below and shown in Figures 20 and 21) in order to attach the base 14 to either the plug cover 18, the spacer 20 or the receptacle cover 70. Although tabs 28 and channels 38, 43, 80 are used as a connection means in the preferred embodiment, any suitable attachment means can be used. For instance, other connection means can be used including but not limited to fasteners and adhesives.

Slots 30, as are also shown in Figure 4, may also be disposed within the base 14. Slots 30 are constructed to receive a contact assembly either a plug contact assembly 16 or a receptacle contact assembly 72 (which is discussed in more detail below and shown in Figures 19 and 24) so that a contact assembly 16, 72 can be mounted within the base 14. Attachment of the contact assemblies, both base and receptacle assemblies, are described in further detail below.

An embodiment of the plug cover 18 is depicted in Figures 10 and 11. Figure 10 depicts an isometric top view of the plug cover 18, and Figure 11 depicts an isometric bottom view. As shown the plug cover 18 is preferably a single molded piece, but alternatively may be constructed from a variety of pieces. The plug cover 18 can be

constructed from any suitable material, but preferably a polymeric type material is used.

As shown in Figures 3 and 10, the plug cover 18 may have a plurality of slots 32 which can each receive a plug contact as best understood with reference to Figures 1 and 3. Figure 1 depicts the plug contacts extended up through the slots 32, and Figure 3 depicts slots 32 being inserted over the plug contacts 59, 61. In the preferred embodiment shown, the slots 32 are arranged in rows and there are ten tines 35 per row. There can be, however, any number of slots 32 and the tines 35 can be arranged in numerous other configurations.

The under side of the slots 32 in each row are two continuous slots 34 as shown in Figure 11. Figure 12 is a cross-section taken along line 12-12 of Figure 10 through a few of the slots 32. As shown, the slots 32 are in the preferred embodiment defined by a pair of opposed sides 31 which are preferably angled away from each other in order to facilitate the insertion of a contact through them. Walls 33 also define a substantially vertically section of the slots 32. The slots 32 may further be defined by tines 35 which extend, as shown in Figures 10 and 12, above the outer surface 36. These tines 35 provide additional support for the plug contacts and further narrow the slots 32, as is also shown in Figure 9. It will be appreciated that a variety of other constructions can be used to form the slots 32. A support member 33a, which is in the preferred embodiment integrally formed with the plug cover 18 as shown in Figures 11 and 13, extends longitudinally across the middle of the plug cover 18 to provide alignment for the plug contact assembly.

Extending from opposing sides of the plug cover 18 may be members 37 that define channels 38. The tabs 28 of the base 14 fit into the channels 38 in order to snap fit the base 14 to the plug cover 18. Alternatively, tabs 44 on the spacer 20 as explained below fit into the channels 38 in order to attach the plug cover 18 to a spacer 20. This construction is shown in the preferred embodiment of Figure 1. In the preferred embodiment shown, there are eight channels 38 on each member 37 that mate with the eight tabs 28 of either the base 14 or the spacer 20, but any suitable number may be used. Alternative means may be used to attach the plug cover 18 to either the base 14 or the spacer 20.

The plug cover 18 has walls 39 which are preferably sized and shaped to

define an interior 40 for receiving a receptacle assembly. Preferably, the receptacle assembly 13 fits snugly within the interior 40 so that a sliding fit is created. The corners 42 of the walls 39 are preferably sized and shaped so that the corners of the receptacle assembly discussed below will snugly fit within the walls 39. It will be appreciated that the plug 12 and the receptacle 13 can fit together with numerous other constructions, and this is one example of a preferred way to attach the two assemblies 12, 13. One or more corners of the plug assembly can be sized or shaped so that those corners mate with only a specific corner of a correspondingly sized or shaped corner of the receptacle cover. This ensures that the covers are mated in the proper orientation.

Figures 14 and 15 depict perspective views of a preferred embodiment of a spacer 20. Figures 14 and 15 are respectively top and bottom perspective views. Preferably, the spacer 20 is a single molded piece. Alternatively, the spacer 20 can be constructed from a plurality of pieces. The spacer 20 may be a polymeric material, but any suitable material may be used. Spacers 20 of different heights can be used with either the plug assembly 12 or the receptacle assembly 13 in order to achieve a connector of the desired stack height. For greater stack heights, taller or more spacers are used and for lesser stack heights smaller or less spacers are employed. In the preferred embodiment, a single spacer 20 is used in the plug assembly 12 and is connected to the base 14 and the plug cover 18 as shown in Figure 1.

The spacer 20 preferably has any suitable means for connecting the spacer 20 to a base 14 or a plug cover 18. In the preferred embodiment shown, the connecting means is a mechanical type connection means and includes the channels 43, which can be mated with tabs 28 of the base 14. The spacer may also have tabs 44 to snap fit the spacer to the channels 38 of the plug cover 18. Preferably, the spacer 20 has channels 43 and tabs 44 on two opposing sides of the spacer 20. Although only one side is shown in Figure 15, it will be appreciated that the other side is similarly constructed.

Disposed within the spacer 20 may be a series of grooves 45 for receiving a contact assembly. The grooves 45 are preferably defined by a plurality of inwardly extending partitions 47 which support the lateral ends of a contact assembly.

The spacer 20 may also have a plurality of legs 49 extending downward. These legs 49 rest on the upper surface 51 of the base 14 when the spacer is disposed on

the base 14, as shown in Figures 1 and 3, and as also understood by comparing Figures 14 and 4. The spacer 20 has surfaces 53 which create windows 55 when mated with the base 14, as best understood in Figure 3. These windows 55 serve to reduce the weight of the spacer 20 and provides a flow path for air into the plug assembly for cooling. The windows 55 are also preferably asymmetric with respect to the centerline. This assists in manufacturing the plug assembly and in orienting the spacer 20 in a vibratory feed system.

Figure 16 depicts preferred embodiment of a plug contact assembly 16 for use with the plug assembly of Figure 1 before the contact assembly 16 is singulated to remove portions 57. The plug contact assembly 16 includes a plurality of alternating ground 59 and signal contacts 61. Any number of such contacts can be used to create a plug contact assembly. In a preferred embodiment, ten ground 59 and eight signal contacts 61 are employed.

The contacts 59, 61 need not be but may be gold striped at their ends 63 which are connected to the solder balls as shown in Figures 8 and 9, to improve wetting of the contacts 59, 61. The mating ends of the contacts 59, 61 can also be gold striped to provide high reliability and relatively low mating forces. The remaining portion of the contacts 59, 61 can be nickel plated to prevent the solder from traveling up the contacts 59, 61. Figure 8 is a cross-section depicting a plug contact assembly 16 inserted into the plug assembly 12 and shows the ends 63 of the signal contacts connected to a solder ball 29 in a ball pocket 25 of the base 14. It will be appreciated that the ends of the ground contacts 59 of the contact assembly shown are in a different plane but are likewise wetted to a solder ball in a ball pocket of the base 14. As shown, the ends 63 of the contacts, extend through the recesses 22 in the base 14 and to the diamond pockets 25 where solder 29 is used to create a solder ball for electrical connection to another electrical component. This is also shown in Figure 9 which depicts a longitudinal cross section through the plug assembly 12. As shown each contact 59 is wetted to the solder 29 in a pocket 25 of the base 14.

The contacts 59, 61 can be stamped and then molded to a plastic carrier 65 an embodiment of which is shown in Figure 16. The ends 67 of the carrier 65 are preferably sized and shaped so that they can fit relatively snugly within the slots 30 of the base 14 and the grooves 45 of the spacer 20. This is best understood with reference to Figure 3, which shows a plurality of contact assemblies 16 inserted into the grooves 45 of

the spacer 20, and Figure 8, which is a cross-section depicting the plug contact assembly 16 inserted into the slots 30 of the base 14 and the groove 45 of the spacer 20.

The assembly of the plug assembly 12 can best be understood by starting with a base 14, as shown in Figures 4 and 5. A spacer 20, if used, can be snap fit to the base 14 by snapping the tabs 28 of the base 14 into the channels 43 of the spacer 20 as shown in Figure 15. The contact assemblies 16 can then be inserted into each of the slots 30 in the base 14 and grooves 45 of the spacer 20. Then as shown in Figure 3, a plug cover 18 can be snap fit to the spacer 20 with tabs 44 and channels 38. Solder can then be inserted in each pocket around the contact end 63 of the contacts 59, 61 to create the solder ball connections. The diamond shape construction of the pockets 25 ensures wetting around the perimeter of the contacts as described above.

If contacts of smaller heights are used, then the spacer 20 may not be required. In that event, the plug cover 18 can be attached directly to the base 14 with the base tabs 28 and the plug cover channels 38.

RECEPTACLE ASSEMBLY

A preferred embodiment of the receptacle assembly 13 to which the plug assembly 12 can be mated is shown in Figures 17 and 18. Figure 17 is a perspective view of the top of the receptacle assembly 12, and Figure 18 is a perspective view of the bottom or underside of the receptacle assembly 12. The receptacle assembly 13 generally includes a base 14, a receptacle cover 70 and a receptacle contact assembly 72, a plurality of which are depicted in Figure 19. Although not shown in the preferred embodiment, a spacer 20 if needed based on contact height could be used between the base 14 and the cover 70. Figure 19 shows the construction of the receptacle assembly 13 with a plurality of receptacle contact assemblies 72 inserted into the base 14, and the receptacle cover 70 being coupled to the base 14.

The base 14 of the receptacle assembly 13 is preferably the same base that is used in the plug assembly 12 and which is depicted in Figures 4-7. Thus, the construction of the receptacle base 14 can be understood by referring to the discussion above. By using a common base for the plug assembly 12 and the receptacle assembly 13, manufacturing is simpler and less costly in comparison to having to produce two different

bases for the plug and the receptacle assemblies.

Figures 20 and 21 depict a preferred embodiment of the receptacle cover 70 which interfaces with the plug cover 18. Figure 20 is a top isometric view of the receptacle cover 70, and Figure 21 is a bottom isometric view. The receptacle cover 70 is preferably a single molded piece, but the receptacle cover 70 may be constructed from a multitude of pieces. Any suitable material but preferably a polymer can be used to manufacture the receptacle cover 70. The receptacle cover 70 preferably has a first portion 74 that is shaped so as to correspond to the interior 40 of the plug cover 18 so that the receptacle cover 70 slide fits into the interior 40 of the plug cover 18 as best understood with reference to Figures 1 and 17. It will be appreciated from viewing Figure 1 that the plug cover 18 of the plug assembly 12 can fit over the receptacle cover 70 to connect the two assemblies and form a connector. The corners 76 of the receptacle cover 70 may be keyed or sized and shaped so as to slidingly engage the corners 42 of the plug assembly 12, so that the two assemblies slide together in an relatively snug sliding fit.

In a preferred embodiment, the receptacle cap 70 has laterally extending portions 78 that each comprise a plurality of channels 80 for receiving tabs 28 of base 14. In a preferred embodiment, there are eight channels 80 in each laterally extending portion 78. The receptacle cover 70 snap fits to the tabs 28 of the base 14 to form the receptacle assembly 13 shown in Figures 17 and 18.

The top of the receptacle cap 70 preferably has a plurality of laterally extending slots 82. These slots 82 are for receiving the plug contacts 59, 61. As will be appreciated by viewing Figures 1 and 17, the plug contacts can extend down through the slots 82 and mate with a corresponding receptacle contact 84 shown in Figure 19. Figure 22 also depicts the receptacle contacts 84 which are disposed beneath a slot 82. The slots 82 are preferably defined in part by opposing walls 88 which are angled toward each to direct the plug contacts 59, 61 to a corresponding receptacle contact 84, 86.

Extending longitudinally along the underside of the receptacle cover 70 is preferably a support member 90. The support member 90 preferably has a plurality of ridges 92 and grooves 94 for receiving a receptacle contact assembly member 96, as shown in the cross-section of Figure 23.

Figure 24 depicts a perspective view of a preferred embodiment of a

receptacle contact assembly 72 that can be used with this invention before it has been singulated to remove portions 98. The receptacle contact assembly 72 includes alternating ground 84 and signal 86 contacts and a plastic carrier 100. Although the contacts differ in construction, the general construction of the receptacle contact assembly 72 can be understood with reference to the discussion regarding the plug contact assembly 16. The receptacle contacts are preferably stamped and then molded to a plastic carrier 100. They are then singulated to remove unwanted portions 98. The ends 102 of the receptacle contacts can be but need not be gold striped to ensure wetting with solder 29 when disposed in a base pocket 25 as shown in Figures 22 and 23. The mating ends of the contacts can also be gold striped for high reliability and to reduce mating forces. The ends 104 of the plastic carrier 100 are preferably sized and shaped so that they can be inserted into the slots 30 of the base 14, as shown in Figure 19.

The receptacle contact assembly 72 can also have support member 96 which as shown in the cross-section of Figure 23 fits relatively snugly within a groove 94 defined by two of the ridges 92 in the support member 90 of the receptacle cover 70. This provides stability for the receptacle contact assembly 13.

As shown in Figures 19, 22 and 24, one end of the receptacle contact 106 has groups of opposing forks 108 that define a space 110 for receiving a plug type contact 59, 61. As will be appreciated by viewing the plug contacts 59, 61 in Figure 3, a plug contact 59, 61 can fit between the forked end 108 of a receptacle contact 84, 86 in order to provide an electrical connection.

The receptacle assembly 13 can be constructed by inserting a plurality of receptacle contact assemblies 72 into the slots 30 of the base 14, as best understood with reference to Figure 19. As described above, the ends 104 of the plastic carrier 100 are sized and shaped so as to fit relatively snugly within the slots 30. The receptacle cover 70 snap fits over the base 14 by snapping the tabs 28 of the base 14 into the channels 80 of the receptacle cover 70, as shown in Figure 19. When the receptacle cover 70 is attached to the base 14, the support members 96 of the receptacle contact assemblies 72 fit within the grooves 94 of the receptacle cover support member 90.

MATING OF THE PLUG AND RECEPTACLE ASSEMBLIES

The plug and receptacle assemblies12, 13 are mated by inserting the receptacle cover 70 into the interior 40 of the plug cover 18. The receptacle corners 76 of the receptacle cover 70 fit relatively snugly into the corners 42 of the plug cover 18 to form a sliding and keyed fit. When coupled together, the plug contacts 59, 61 shown in Figure 3, extend through the slots 82 of the receptacle cover 70 and mate with a corresponding receptacle contact 84, 86 to create an electrical connection between each contact. The connector can be mated to other electrical components such as printed circuit boards which have circuits that can be placed in electrical contact with the plug 59, 61 and receptacle contacts 84, 86 and the solder balls 29 which surround them.

Figure 24A is a schematic diagram of the arrangement of the signal and ground contacts in the first preferred embodiment. The signal and ground contacts are oriented in what is referred to as an "in-line stripline" configuration. In this configuration, there are individual ground contacts 59, 84 on either side of each signal contact 61, 86, which can also be understood with reference to Figures 3 and 19. As will be appreciated from Figures 3 and 19, individual ground contacts 59, 84 are disposed on either side of the signal contacts 61, 86 to provide an electrical ground reference for the signal contacts and to provide the electrical stripline configuration. The geometric relationship between the signal and ground contacts, including the gap H, the thickness t, the width w and pitch p, can be varied to achieve the desired connector impedance and electrical performance.

Although this invention is not limited to such in-line stripline configurations, the in-line stripline configuration has several advantages (relative to the I-Beam approach described below) including advantages in terms of costs and manufacturing. For example, the same contact can be used in all locations, and the contacts can be continuously stamped, which produces relatively consistent contact gaps (H). This is beneficial in achieving the desired optimum electrical performance. Additionally, all connector contacts can be used for either differential or single ended signals or any combination of these. Molding of the carrier 104 shown in Figure 24 is also easier because the contacts can be molded in a vertical row with contacts oriented so that the thin width is in the direction of mold closing. Another advantage is that because ground planes are not used, the connector mass (including its thermal mass) is lower

which results in easier application to customers' printed circuit boards (PCB).

Figure 24B depicts a mezzanine in line stripline configuration in which the signal contacts are surrounded by ground contacts. This configuration is advantageous in reducing cross-talk.

ALTERNATIVE EMBODIMENT

Numerous variations of the plug assembly and the receptacle assembly set forth above can be made without departing from the spirit of the inventions set forth herein. Examples of such variations include but are not limited to ways to connect the plug and receptacle assemblies and their components, the arrangement of contacts within the assemblies, the configuration of the contact assemblies, the support for the contacts, and the shape and size of the assemblies.

One alternative embodiment is set forth in Figures 25-30. Figure 25 depicts an embodiment of plug cover 518 attached to a spacer 520 which can be used to form a plug assembly 512. A plurality of plug contact assemblies are installed within the plug cover 518 and the spacer 520. (Although only a few plug contact assemblies 516 are installed, it will be appreciated that the assembly could be filled with plug contact assemblies 516). Figure 26 illustrates a receptacle cover 570 detached from a spacer 520 and a plurality of receptacle contact assemblies 572 installed within the spacer 520. The receptacle cover 570 and the plug cover 518 can be snap fit to the spacer 520. Although Figures 25 and 26 depict spacers 520 being used in the plug and receptacle assemblies, it will be understood that either assembly could be made with or without a spacer 520. Spacers 520 are used if the contact height dictates their use.

Figures 27 and 28 respectively illustrate a top and bottom perspective view of an embodiment of a common base 514 that can be used with both the plug assembly shown in Figure 25 and the receptacle assembly shown in Figure 26. The common base 514 can attach to the spacer 520 used in either assembly. In this embodiment, the tabs 528 of the base 514 are snap fit to channels (not shown) in the spacers 520.

The common base 514 has slots 530 for receiving either a plug or a receptacle contact assembly 516, 572. As shown in Figure 27, which is a top view of the base 514, recesses 522 are disposed in the top 514a of the base 514 similar to those described in the first embodiment. A pair of opposing angled walls 524, 526 create each

recess 522 and narrow the recess 522 to facilitate the insertion of a contact end through the recess 522. Diamond shaped pockets 525 are disposed on the bottom 514b of the base 514 beneath each recess 522. The diamond shaped pockets 525 are configured as in the first embodiment, so that the end of the contact extending through the recess 522 will have clearance to receive solder 529 around its periphery.

Figures 29 and 30 depict an embodiment of a receptacle contact assembly 572. The receptacle contact assembly 572 has a plurality of receptacle contacts 584, a pair of ground plates 606 and a pair of plastic carriers 608. The receptacle contacts can be formed by stamping and then being molded to the plastic carriers 608. The plastic carriers 608 may have protrusions 610 extending laterally for insertion into a corresponding hole 612 in a ground plate 606, as shown in Figure 29.

Although Figures 29 and 30 depict a receptacle contact assembly 572, it will be appreciated that plug type contacts could be substituted for the receptacle contacts and the plug contact assembly 516 would otherwise be the same as that depicted in figures 29 and 30. The contact assemblies 516, 572 are mounted within the plug 512 and the receptacle 513 by fitting either end of the ground plates 606 of the contact assembly 516, 572 in the slots 530 of the base 514 and the grooves (not shown) of the spacer 520. This is best understood with reference to Figure 26.

The plug and the receptacle of this second embodiment can be mated together by inserting the receptacle cover 570 into the interior of the plug cover 518. It will be appreciated that the receptacle and plug covers 518, 570 are sized and shaped so as to from a relatively snug slide fit. When mated, the plug contacts extend through the slots in the receptacle covers to create electrical connections between the contacts.

Figure 32 is a schematic description of the configuration of the contacts in the second embodiment. This arrangement is referred to as a stripline I-Beam configuration. In this configuration ground plates 606 provide the electrical ground reference for the signal contacts. This is in contrast to the in line stripline approach described above which uses individual ground contacts. The geometric relationship including the pitch p, the thickness t, and the gap h, and the width w can be controlled to obtain the desired connector impedance and electrical performance. Although the in-line stripline configuration has some advantages, which are noted above, it will be understood,

that either the in-line stripline or I-Beam stripline configuration can be used to obtain the desired electrical performance.

An adaptor can be used with various combinations of plugs and receptacles. For example, Figure 31 depicts an embodiment of an adaptor 610 that can be used to form a plug to adaptor to plug assembly. The adaptor 610 can be manufactured from plastic or any suitable material. The adapter 610 is constructed so as to mate with two plugs 512 when longer connections are needed than just the plug 512 to the receptacle 513. The adapter 610 can be attached at one of its ends 612 to the plug 512 and at the other end 614 to another plug 512. The adapter 610 can be constructed from a receptacle cover 570 at either end for mating with a plug assembly 512. The adaptor 610 can also have none or one or more spacers 520 depending upon the length of the connection needed. A plurality of contacts can be installed within the adapter that have ends for mating with plug contacts. Although the embodiment adapter 610 shown is for use with the second embodiment, it will be appreciated that the adapter 610 can have other embodiments including one for mating with the first embodiment shown. Although a plug to plug adaptor 610 has been described, it will be appreciated that a receptacle to receptacle adaptor could be formed, as well as various other combinations of plug and receptacle adaptors.

SUMMARY

By using the plug 12, the receptacle 13, the spacers 20 and the adapter 110, if needed a modular connector assembly can be formed that accommodates a selected stack height. After selecting a stack height, the proper contact height and contact assembly for both the plug 12 and the receptacle 13 can be selected. The plug and the receptacle contact assemblies 16, 72 of the selected stack height can be inserted into and coupled to the base 14 of the respective plug 12 and the receptacle 13. If needed for the stack height, one or more spacers 20 can be connected to either or both the receptacle base 14 and the plug base 14. For the plug, the plug cover 18 can then be coupled to the base 14. Alternatively, for larger stack heights one or more spacers 20 can be attached to the plug base 14, and the plug cover 18 can be mounted to the top spacer 20. For the receptacle 13 a receptacle cover 70 can be coupled to the base 14. Similarly, for larger stack heights one

or more spacers 20 can be attached to the receptacle base 14, and the receptacle cover 70 can then be attached to the top most spacer 20. Then the plug 12 and the receptacle 13 can be mated by attaching the plug cover 18 to the receptacle cover 70. If needed, based on the length of the connection, an adaptor 110 can be attached to the receptacle 13 and the plug 12 or to two plugs or two receptacles instead of attaching the receptacle directly to the plug 12. The plug base 14 can then be attached to a board or other electrical component, and the receptacle base 13 can likewise be attached to a board or another electrical component.

With the base 14, the spacers 20, covers 18, 70 and adapters 110 a modular connector can be constructed to accommodate a selected stack height. The modular connector need only include those components needed for the given stack height. This is advantageous because a modular connector can be built with the given components to any desired stack height. A new type of connector need not be designed for each stack height. This simplifies the manufacturing process because a variety of components can be manufactured to make a variety of connectors instead of dedicated components for connectors of different heights. For example, a common base 14 is used for both the plug and the receptacle assemblies 12, 13. Moreover, an adapter 110 can be used with common components including a receptacle cover and a plug cover, and each assembly can use a common spacer.

Although this invention has a variety of applications, one such application is in connectors having a stack height between the range of about 10-35 mm. and contact quality of about 100 to 400 signal contacts per connector. One advantage of the connectors of this invention is the interstitial diamond pattern of pockets 25 in the base 14. This provides for closely packing the contacts to maintain the size of the connector relatively small while maintaining a good signal and low cross talk. The diamond shape pockets 25 also ensure good contact wetting or solder attached around the entire periphery of the contact ends. This as described above ensures good electrical performance.

It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size and arrangement of parts within the principles of the invention to the full extent indicated

by the broad general meaning of the terms in which the appended claims are expressed.